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USE OF RADIOTELEMETRY IN SPACE MEDICINE

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ABSTRACT. Discussion of systems transmitting biomedical data from manned spacecraft in orbit. The physiological measuring system in Vostok-3 and Vostok-4 capsules is described. The concerted effort between physicians, physiologists, physicists, mathematicians and chemists in the field of space medicine is stressed. No suggestions for the use of space medicine on the ground can be offered at this time, but a sharing of experience between terrestrial and space medicine must be continued.

A major challenge confronting space biology involves transmission of biomedical data from spaceships and orbiting spacecraft. The information is a requisite in reaching a three-point objective. First, an effective medical check-up of the astronaut's general condition must be maintained so that a quick decision could be taken, according to medical indications, as to whether the flight should or should not be continued. Second, a prognosis concerning the astronaut's condition should hold for a time interval required for the return and landing of the spacecraft from any given point along its orbit. Third, information transmitted in the course of the flight, as well as the records made available with the return of both spacecraft and pilot, are indispensable for scientific purposes. It is on the basis of such information, among other things, that more distant space flights of longer duration will be planned and made feasible.

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The technical means now available for the gathering and transmission of biomedical data include: 1) ratio telephony capabilities, which enable the physician to ascertain how the astronaut feels and, when necessary, to evaluate the nature of his complaints; 2) telemetering systems designed to transmit the astronaut's functional indices as well as the hygienic parameters of his ambient medium; 3) spacecraft-to-earth television which makes it possible to follow up directly the astronaut's activity, postures and locomotion.

Thanks to these combined technical capabilities, the physician is no longer isolated from the astronaut by the vastness of outer space. He can interrogate his orbiting patient, examine him, check the objective symptoms. What is more, he can assume the responsibility for prescribing such medications as are available in the spaceship's medicine chest, or advise what steps are to be taken to alter the environmental hygienic conditions. Critical objective evidence can be telemetered, indicating the effect of the flight factors upon the astronaut. Bio-telemetry, furthermore, enables an objective examination, checkups and prognosis of the astronaut's functional condition, including the extreme states.

*Numbers in the margin indicate pagination in the foreign text.

Of the great many functional diagnostics techniques and clinical tests now in use, the methods selected for the purposes of biotelemetry were those that had proved suitable for automation and could be employed effectively for oft-repeated or continuous, lengthy testing with no outside assistance. Special types of electrodes were designed, for example, which could be implanted permanently in the astronaut's body for a period of 3-5 days, causing no discomfort (N. A. Agadzhan-yan, I. T. Akulinichev, K. P. Zazykin and D. G. Maksimov). It was found that qualitative electrocardiograms of the astronaut when engaged in vigorous physical activity could thus be obtained. Since any radiofrequency channel has a fixed transmitting capacity, more effective techniques had to be found for converting physiologic indices into adequate electric values. The background data as well as individual physiologic normals were established in preliminary tests for each astronaut. This was important, in terms of efficient follow-up checking, inasmuch as any deviation from normal could be identified more positively and with greater precision. Such deviations could in fact be predicted for the various stages of the space flight.

The information value implicit in each physiologic parameter was assessed with a view to better utilization of the transmitting capacity specified for the telemetry channels. The next step was to screen superfluous data, while condensing the more useful portion. A way was found to transmit two parameters simultaneously through a single channel.

No less challenging difficulties had been overcome in developing spacecraft-based physiological testing equipment. Highly sensitive instrumentation of rigorously predetermined weight specifications and power requirements was to be designed to fit into the limited available space. The equipment, moreover, had to be relied upon to deliver a stable performance when operated over a broad temperature range, without being affected by overloading, vibrations, changes in pressure, elevated moisture and an altered composition of the gaseous medium. The diverse modifications of physiological equipment designed earlier for the launching of rocket probes and orbital satellites carrying experimental animals furnished invaluable test data. The ground work had thus been laid for further advances, in which testing procedures were selected and a physiological measuring system was devised for spaceships "Vostok". The system was based on thoroughly worked-out operating principles. It performed well from the initial through the final launching, undergoing some modernization with additional refinements in the interim. The complete outfit includes sources of primary information, electrodes and data pickups, an amplifier unit and transducers, delivering a data output suitable for being fed to the spaceship's telemetering and recording equipment.

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By way of illustration we shall describe in some detail the physiological measuring system of spaceships Vostok-3 and Vostok-4 (Fig. 1). The six telemetering channels served to test: 1) The electric activity of the brain, derived from the fronto-occipital region (EEG); 2) electric activity of the eyes and oculomotor muscles (EOG); 3) electric activity of the heart, in a bipolar thoracic derivation (DS); 4) respiratory changes in the thorax perimeter (PG); 5) cutaneogalvanic reflex in the area of the foot; 6) the rhythmic pattern of heart contractions. The complete set of the physiological testing equipment designed for the spaceship included: 1) miniature preamplifiers (EEG and EOG) with a controlled

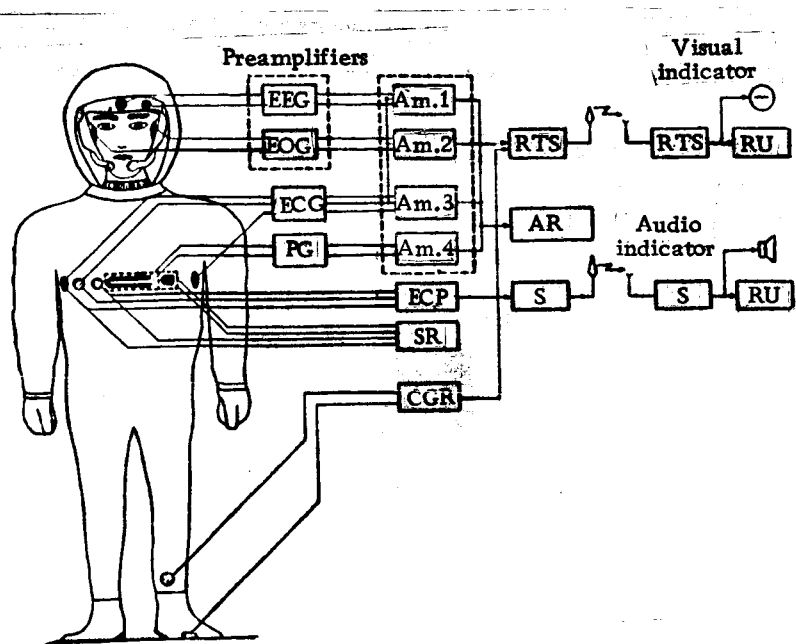


Figure 1. Physiological Measuring System Installed in Spaceships Vostok-3 and Vostok-4. RTS-radio telemetering system; AR-airborne recorder; C-signal transmitter; ECP-electrocardiophone; SR-self-contained recorder; Am. 1, 2, 3, 4-amplification channels for EEG (electroencephalograms), EOG (electrooculograms), ECG (electrocardiograms), PG (pneumograms) and CGR (cutaneous galvanic reflex); RU-recording unit.

(10-80) gain factor, which were affixed in various places to the astronaut's spacesuit; 2) three amplifier units (Nos. 1, 2, 3) with a 2000 gain factor within the bandwidth 0.2-50 cps and one amplifier unit (No. 4) with a gain factor of 50 over the frequency range 0.1-10 cps; 3) an electrocardiophone (ECP) designed to amplify the shape audio signals of a frequency corresponding to the cardiac rate; 4) self-contained recorder of both cardiac and respiration rate (SR); 5) an indicator recording the cutaneous galvanic reflex (CGR).

The physiological equipment was fully transistorized, with consequent compactness, low weight and low power consumption. Figure 1 shows further the spaceship instrumentation (the radio telemetering systems, both spacecraft- and ground-based, the ship's recorder, and the signal transmitter with the related ground installation). The two systems constituted an interlocking arrangement.

Typical trace records obtained for the astronaut A. G. Nikolayev during his space flight are shown in Fig. 2.

From the brief description of the biotelemetering system installed in spaceships "Vostok" it is evident that such instrumentation cannot be either designed

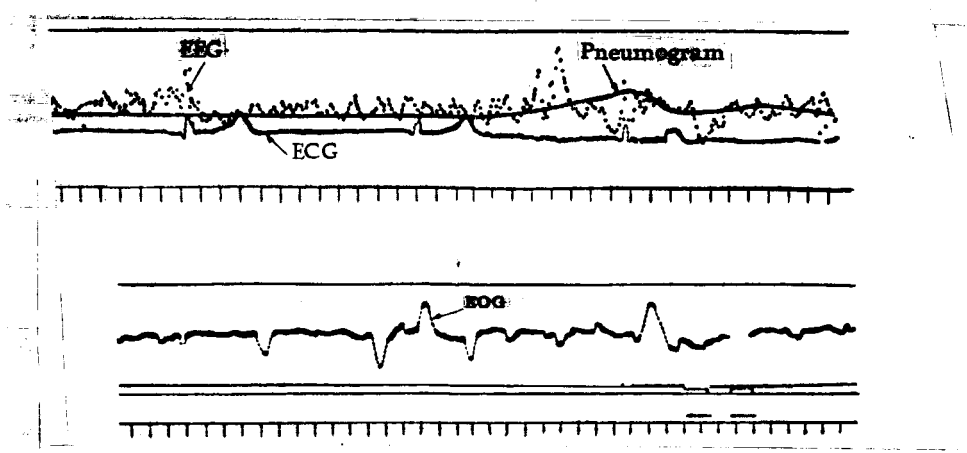


Figure 2. Typical Trace Records of Physiologic Indices Obtained for A. G. Nikolayev During This Space Flight.

or operated with sufficient technical know-how. It is for this very reason that in space medicine, as in no other field previously, we are now witnessing an unprecedented phenomenon of cooperation and concerted effort uniting physicians and physiologists with physicists, mathematicians, chemists and electronic equipment designers in a common task. Conditions have been created conducive to the interpenetration of diverse sciences and the shaping of bold scientific ideas and hypotheses. The beginnings of space biotelemetry can be traced back to the clinical and physiological laboratories where the basic methods have been developed. Today it advances blazing its own trails, contributing its own research techniques to science in general. These lines of development encompass: 1) a search for the most efficient methods of deriving and converting physiological data; 2) designing compact (intra-cabin) telemetering systems of high resolving power and long-term action; 3) devising methods for automatic processing of information, with suitable instrumentation provided for the purpose.

Further refinements in the biotelemetering systems will come with future advances in astronautics, as more distant flights of longer duration become feasible. This will naturally widen the scope of physiological tests to be applied. If such were to increase in number indefinitely, however, the astronaut embarking on a space flight would in the near future have his entire body "studded" with electrodes and data pickups, which would interfere with his work. A simple solution of this problem was proposed in 1961 by O. G. Gazenko and G. M. Bayevskiy. During distant flights of long duration, according to these authors, only a few of the electrodes and data pickups would be permanently carried by the astronaut. An effective running checkup of the crew, to follow up the men's general condition, could then be maintained on the basis of such elementary physiologic indices as the pulse rate, respiration, body temperature, and the like. The basic equipment would be used only for periodic medical tests following a specific program. The astronaut would himself put on and then take off the required electrodes and data pickups. Such testing, needless to say, would have to be fully automated. The "automatic polyclinic" idea, it seems, might eventually be adopted for medical services under terrestrial conditions.

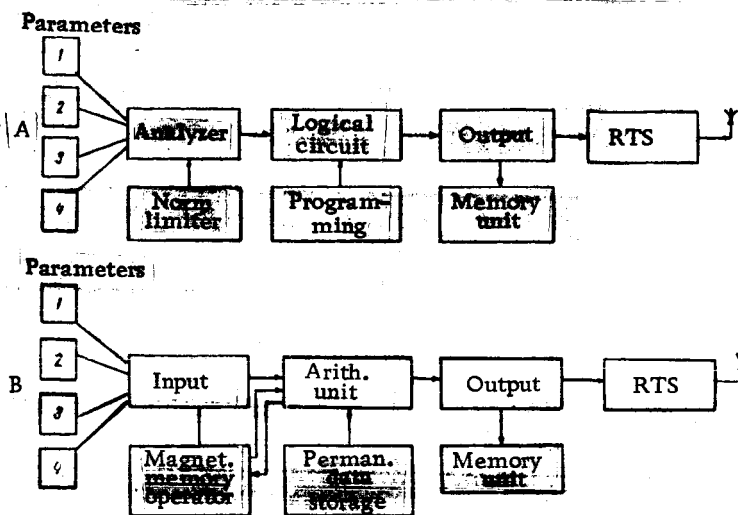


Figure 3. Automatic Processing of Medical Information on Board Spaceships With the Aid of a Logical Net (A) and a Digital Computer (B).

It should be kept in mind that for more distant space flights of increased duration the possibilities, in the ship-to-earth transmission of information, will be increasingly limited. The reduced throughput of the telemetering channels will pose some problems related to maximum information transmission over limited capacity channels. The solution, it is now clear, will be based largely on use of a spaceship-based computer assembly. Either digital computers or the simpler logical circuits (V.I. Yazdovskiy and R.M. Bayevskiy) may be used. In either case data derived from the astronaut must be

fed directly to the information processing assembly (Fig. 3). No less important is the use of radio telemetering systems operating inside the cabin. The astronaut, relieved of the cumbersome connectors linking him with the outside equipment, will be able to operate with greater facility in the course of a long flight.

The space biotelemetry techniques could be applied successfully under the terrestrial conditions. We cannot at this time offer any comprehensive suggestions as far as the possible "ground" uses of space medicine methods are concerned. A few preliminary considerations may however be presented.

We shall first call the reader's attention to the system devised for a long-term follow-up of the subject's condition, which includes such parameters as ECG, pneumogram, EEG, CGR (cutaneogalvanic reflex), etc. This system could be applied in operating rooms, the intensive care wards for severe cases, as well as in checking an operator's condition under exceptional circumstances. Of distinct interest, among other things, are bipolar chest electrodes characterized by high noise immunity, which are designed for data derivation from the axillar and sternal areas; a new data pickup for studying the mechanical processes associated with cardiac activity; a simple indicator for the cutaneogalvanic reflex, and so forth. A valuable addition to the componentry of medical instrumentation could be found in the miniature preamplifiers for use in electroencephalography and electroculography, which would broaden considerably the methodological scope of testing techniques by means of the conventional electrocardiograph. This applies also to the stable transistorized amplifiers for a battery-powered portable electrocardiograph. Another device to be recommended for general use is an electrocardiophone of simple design which converts cardiac biopotentials into a series of audio signals reflecting the rhythmic pattern of heart contractions. The electric circuits of some of these devices are shown schematically in Fig. 4. The

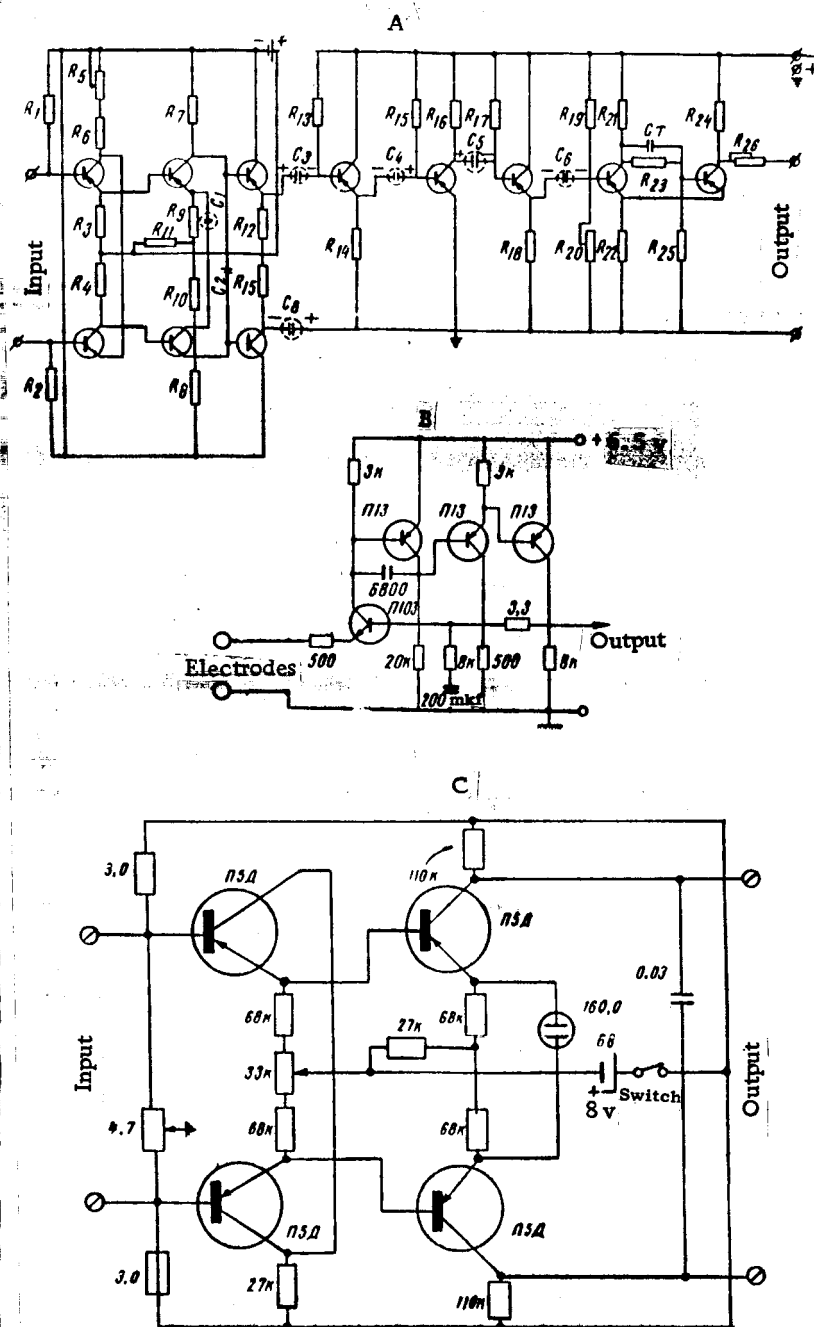


Figure 4. Basic Electric Circuits for an Automatic Indicator of Cutaneogalvanic Reflexes (A), Electrocardiophone (B) and Preamplifier for an EEG Recorder (C).

electrocardiophone was designed by V. F. Freydel' and co-workers; the automatic indicator of the cutaneogalvanic reflex, by I. T. Akulinichev; the preamplifier, by V. V. Bogdanov and collaborators.

Of the methods now being developed with a view to making possible distant space flights of long duration, some useful clinical tests could be based on simple electronic logical systems signaling the danger point in the patient's condition. A distinct, rigorously preassigned overall deviation pattern from normal noted for a number of parameters selected for testing would serve here as the monitoring factor (R. M. Bayevskiy and coauthors). Of some further interest is the instrumentation devised for a long-term telemetry checkup of the astronaut's condition when cooped up in a small air-tight cabin.

It might be added that while the first steps of space biotelemetry had been guided directly by the previously accumulated "terrestrial" experience, today we witness the appearance of some distinctive trends and original techniques adapted specifically for the conditions of space flights. A generous and fruitful sharing of experience, between "terrestrial" and space medicine, should therefore be carried on as before.